Converging Frontiers in Biomedical Engineering from Novel Research to Patient Benefits

PROCEEDINGS

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Edited by 編輯
William Lu

Organiser 舉辦單位
Biomedical Division
The Hong Kong Institution of Engineers
香港工程師學會生物醫學分會

Co-organiser 協辦單位
Hong Kong Productivity Council
香港生產力促進局

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CONFERENCE ADVISORY COMMITTEE

*In alphabetical order of surnames

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Ir Albert KF POON  Senior Electronics Engineer
Electrical and Mechanical Services Department
The Government of HKSAR

Prof YT ZHANG  Professor, Department of Electronic Engineering
The Chinese University of Hong Kong
A NOVEL SURFACE MODIFIED BIODEGRADABLE METALLIC MATERIAL FOR ORTHOPAEDIC IMPLANTATION


1Department of Orthopaedics and Traumatology, The University of Hong Kong, Pokfulam, Hong Kong, China
2Department of Physics and Materials Science, City University of Hong Kong, Kowloon, Hong Kong, China
ken-cheung@hku.hk, http://www.hku.hk/ortho/ortho

INTRODUCTION
Metallic implants are often used for fracture fixation. However, stress-shielding effect may be resulted in some cases, thereby leading to bone loss around the implant [1]. Those metallic implants may be removed after fracture has healed. Therefore, biodegradable implant is a good alternative to help reduce the morbidity rate and costs to health care system due to second surgery. However, the major challenges of the use of degradable implant are rapid degradation inside human body and hydrogen gas release upon degradation. Therefore, improving its corrosion resistance is the primary objective prior to applying the degradable implant for clinical use. Hence, our group has recently developed a unique method to deposit a biodegradable polymer named polycaprolactone (PCL) on the surface of magnesium alloys. Previous in-vitro studies suggested that the rate of degradation of the magnesium alloy has been delayed. Hence, this study aims to test the biocompatibility of this coated magnesium alloys under in-vivo conditions.

METHODS
Polymer coated magnesium alloys were prepared by dipping and vapour deposition with the use of PCL solution. Three concentrations named PCL-low, PCL-medium and PCL-high were made by dissolving 1g of polymer granules into 20ml, 30ml and 40ml dichloromethane (DCM) respectively. Two of each PCL-low, PCL-medium, PCL-high and uncoated AZ91 magnesium alloy with 3mm in diameter and 6mm in length were implanted into the greater trochanter of four New Zealand white rabbits respectively. The bone tissues with implants were harvested at the second month of post-operation and fixed in 10% buffered formalin. All the samples were then embedded in methyl-methacrylate for subsequent analyses. The total volume of implanted magnesium rod and the volume of new bone formation were evaluated by using micro-CT (Skyscan Company). Afterwards, the embedded tissue blocks were then sectioned and ground to 50μm for histological Ginesa analysis. The on-growth of new bone and the integration of implanted material to host tissue were observed under optical microscope.

RESULTS AND DISCUSSION
From the micro-CT results, corrosion was found in uncoated and PCL-high samples but not in PCL-low and PCL-medium samples. Table 1 shows the percentage change in implant volume and newly formed bone volume. The uncoated magnesium alloy showed the least new bone formation and the most implant volume reduction after two months implantation. The result suggested that the uncoated implant had the fastest corrosion rate but the polymer coated samples showed no or less degradation at the two months time point. Although PCL-high sample had corroded, its volume reduction in total was only 0.05%, which was smaller than that of the uncoated sample. Nevertheless, more new bone formation was found. The existence of newly formed bone tissue around all the implants confirmed their biocompatibility. New bone (blue arrows) and osteoblasts (green arrows) were observed in Figure 1. No adverse biological effect was found around all the implants, including the uncoated sample. Similar results were found in others’ findings. Both Witte et al. [2] and Xu et al. [3] suggested that new bone formation was found around their magnesium-based alloys although corrosion occurred. However, according to our result, the uncoated sample got the least amount of new bone formation than the coated samples. This was purely related to the large amount of magnesium ion release. As demonstrated in the previous in-vitro cytotoxicity test, the osteoblastic activity was inactivated by the high magnesium ion concentration during rapid corrosion. Therefore less new bone was formed around the uncoated sample than the coated samples.

<table>
<thead>
<tr>
<th>Sample</th>
<th>New bone volume</th>
<th>% change in implant volume</th>
</tr>
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<tbody>
<tr>
<td>Uncrcoated</td>
<td>1.36 mm$^3$</td>
<td>0.33%</td>
</tr>
<tr>
<td>PCL-low</td>
<td>6.71 mm$^3$</td>
<td>0</td>
</tr>
<tr>
<td>PCL-medium</td>
<td>10.79 mm$^3$</td>
<td>0</td>
</tr>
<tr>
<td>PCL-high</td>
<td>5.17 mm$^3$</td>
<td>0.05%</td>
</tr>
</tbody>
</table>

Figure 1. Microscopic view of histological analysis of bone tissue formation around the implants. (a) Uncoated, (b) PCL-low, (c) PCL-medium and (d) PCL-high

CONCLUSIONS
From the in-vivo animal study, the polymer coated magnesium alloys are able to reduce the rate of degradation as compared with uncoated alloys. In addition to suppressing the release of magnesium ions, the PCL polymer coating does not discourage the new bone formation. However, long term animal study is still required before these surface modified magnesium alloys can be applied in clinical use.

REFERENCES
2. Witte F et al. Biomaterials 26, 3557-63, 2005

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